Alabama Agricultural Stakeholder's Perceptions of Weather and Climate-Based Information and the Influence of these Perceptions on the Decision-Making

by

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ABSTRACT

Climate change is causing long-term weather changes such as increases in temperature and variations in precipitation. Climate change can have major effects on producers as agriculture is dependent on the weather. The adoption of climate smart agriculture (CSA) is one way to increase resilience. Careful considerations are required to adopt CSA tools and practices including when and which technologies are used, how much they will cost in both the short-term, and what long-term benefits are expected. The complexities in decision-making require understandings of how producers and their advisors articulate weather and climate perceptions and how they perceive the role of CSA. Understanding these perceptions aids in the co-development of knowledge (CDK) process. CDK is an emerging strategy for producing research that is meaningful and useful to agricultural stakeholders. To explore one aspect of the CDK process, this thesis examines two key questions: "How do stakeholders (i.e. producers, crop consultants, Extension agents) perceive weather and climate?" and "How do these perceptions influence the use of climate-smart technology?" For this analysis, 38 interviews including producers (n=25), crop consultants (n=6), and Extension field agents (n=7), as well as 23 stakeholder events were recorded, transcribed, and analyzed. Through meteorological, technological, and socioeconomic keyword searches, perceptions among all stakeholders studied were found to be more negative toward weather and climate (e.g., perceived distrust and uncertainty in weather forecasts). There were fewer positive mentions (e.g., beneficial weather phenomena). Making decisions for the farm is a multi-faceted issue. Weather is one influence in the use of climate-smart technology; however, weather is not the only factor influencing these decisions as economics is also a crucial factor in decision-making.

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INTRODUCTION

Climate change is causing increases in temperature and variations in precipitation. Climate change impacts especially affect agricultural producers who are dependent on the weather and the climate. Weather is the atmospheric conditions at a specific time and place, while climate is weather conditions over a time period. Climate-smart agricultural (CSA) tools and practices are intended to increase farmers' resilience when faced with weather and climate challenges. A number of studies have focused on CSA (e.g., Duke et al. 2022, Wang and Cai 2009) including the adoption of tools such as cover crops (Duke et al. 2022), variable rate irrigation (Perry et al. N.d.), soil sensors, and nutrient management (Rudnick et al. 2023). These studies draw on a 65-year history of technology adoption studies by scientists such as Rogers (1958) and Nowak (1987).

Alabama has very low rates of CSA adoption. For example, in 2017, only 15% of agricultural land in Alabama was irrigated, as compared to Mississippi's (61%) and Georgia's (40%) (Sparks 2017). When considering smart irrigation, these numbers are much smaller. Previous work such as Wakweya's (2023) cites a limited awareness of CSA principles, a lack of funding for CSA technology, and uncertainty in how farmers and policymakers should balance aspects of CSA as the main challenges to adoption. CSA is very knowledge-intensive (Wakweya 2023). Thus, researchers, crop consultants, and Extension personnel are useful assets in aiding producers to increase their knowledge about CSA. Collaboration among these stakeholders can contribute toward the co-development of knowledge (CDK) about CSA tools and practices (Wakweya 2023). Ramirez (2013) has shown that producers, for example, adopt irrigation technology most frequently when they interact with neighbors who utilize them. In a thesis written about peer-to-peer learning, it was found that producers preferred hearing what their

neighbors were doing by visiting other farms and interacting with their peers (Robinette 2023). Verbal, informal conversations, as well as observation, can lead to an overall increase in CDK.

CDK is the process in which stakeholders and researchers learn from each other to increase knowledge. This collaboration is necessary to conduct research and develop technologies that are trusted meaningful, and useable for producers and agricultural advisors (Woodall et al. 2021). Researchers learn what producers need and can integrate these needs into programs of research and Extension. CDK opens space for participants (e.g., crop consultants, farmers, Extension agents) to have a voice in research and technology development.

Stakeholders who have knowledge of how weather and climate influence agricultural production may be better positioned to understand why CSA is important. In addition, their perceptions of these phenomena can affect decisions to utilize CSA, and in turn, influence producers' ability to adapt to a changing climate (Makate and Makate 2022; Mbwambo et al. 2021). For instance, if stakeholders do not perceive long-term risks from climate change, they may be less apt to adopt CSA (Reddy et al. 2022). Thus, this thesis examines how producers and agricultural advisors perceive weather and climate and how these perceptions may influence on-farm decision-making. Careful considerations are required to adopt and use CSA including which tools and practices to use, how to use them, and how much they will cost in both the short- and long-term. Moreover, understanding the role of perceptions in CSA decision-making, as well as the ways in which producers and agricultural advisors articulate their perceptions, is one aspect of understanding the CDK process.

To explore an aspect of CDK, this thesis examines two key questions: "How do stakeholders (i.e. producers, crop consultants, Extension agents) perceive weather and climate?" and "How do these perceptions influence the use of climate-smart technology?"

BACKGROUND

My research is part of a larger project, the *Future of Farming: Increasing Adoption of Conservation Practices among Alabama Row Crop Farmers* (FOF), which has been ongoing since 2020. The FOF project is funded by a National Resource Conservation Services (NRCS) Conservation Innovation Grant (CIG). The Primary Investigators consist of two Alabama Cooperative Extension Specialists, a Crop Soil and Environmental Sciences professor, a Rural Sociology professor, and an external consultant who is an Agricultural Economist. A team of graduate students and postdoctoral scholars assist the Research-Extension faculty with related sub-projects.

FOF uses three strategies to learn about the challenges that Alabama row crop producers face in using CSA. First, the FOF project includes an incentive program to assist producers in offsetting the cost of trying cover crops. With this incentive program, farmers are expected to share their experiences with the FOF Research-Extension team and relevant stakeholders so they can learn about the challenges of cover crop adoption. Second, three cooperator-farmers, one in each major growing region--north, central, south--agreed to allow the team to test and demonstrate key technologies in their fields and act as a bridge in creating a learning network. Third, a Farmer-Focused Learning Network was created to provide a venue where the Research-Extension team and a wide range of stakeholders could share information about CSAs. The learning network meets during regularly scheduled field days throughout the year. The attendees include government representatives, Extension agents, crop consultants, producers, and other researchers who discussed and learned about nutrient management, cover crops, and irrigation. These events included guest speakers, on-farm visits, “serious games,” and peer-to-peer discussions. Thus, the learning networks are intended to promote the CDK of CSA.

LITERATURE REVIEW

Keywords such as farmer, perception, and climate change were used in a bibliometric search of the Web of Science. This search helped identify the main topical areas of interest within the peer-reviewed literature. The results yielded four intertwined areas of work: technology (i.e. conservation tools and practices), biophysical sciences (i.e. agriculture and meteorology), social science (i.e., sociology and economics), and research methods (Figure 1). The most common topics of the studies identified included climate change, crops, costs of farming, perceptions, and concerns. There is a notable gap with respect to Alabama and the Southeast. Instead, many studies took place outside the United States (e.g. Nepal, Budhathoki, and Zander 2020; Chile, Roco et al. 2015; Sweden, Asplund 2015), in regions where producers are likely to have different views due to varying politics and sociodemographics. In the US, factors such as economics (Wang and Cai 2009), weather and climate (Chen et al. 2021; Wang and Cai 2009), and farmer's perceptions (Church et al., 2017; Wang and Cai 2009; Roesch-McNally et al. 2018) were found to influence the adoption of technologies such as irrigation scheduling and cover crops.

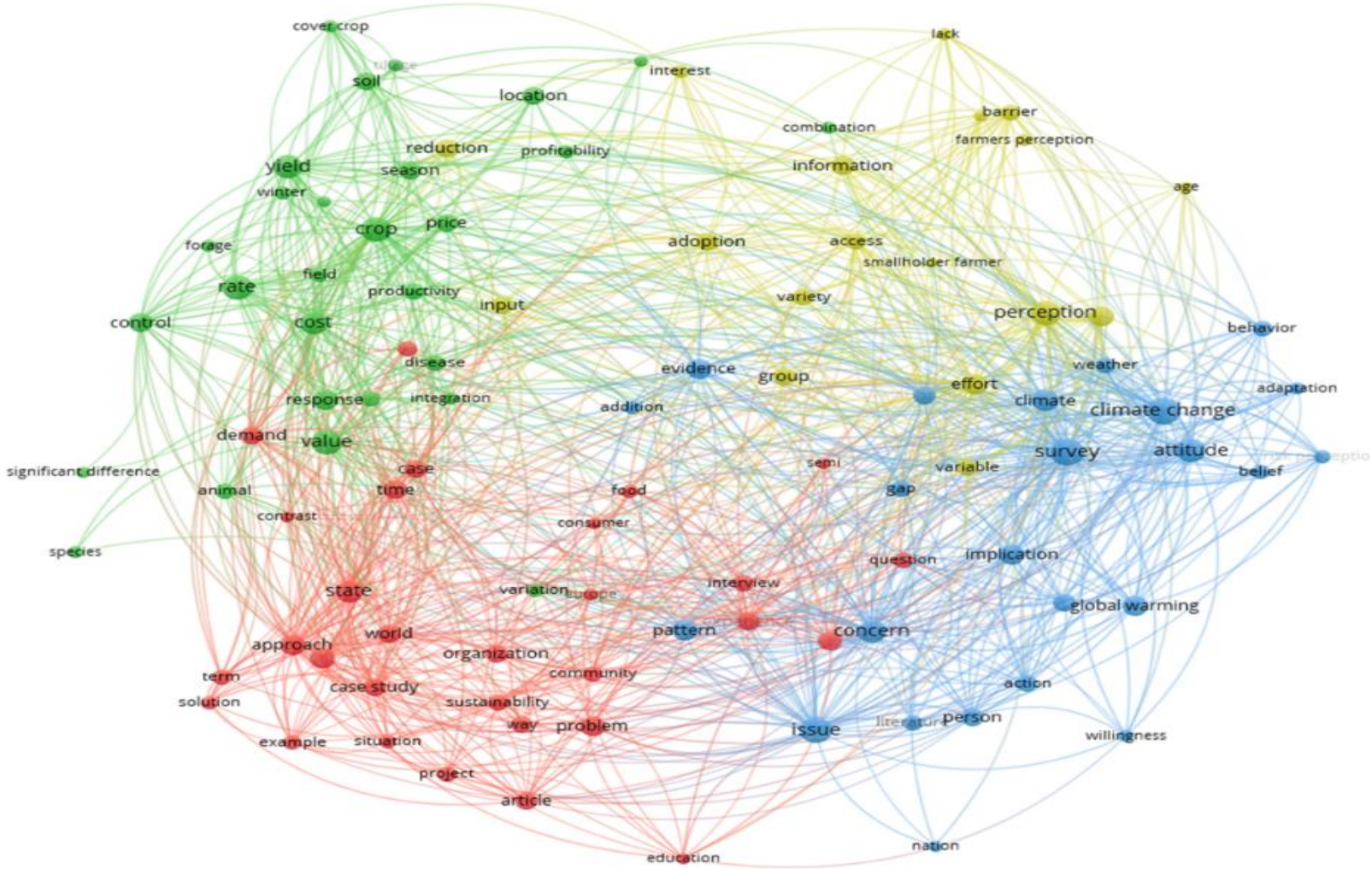

Figure 1: Bibliographic Network of Literature on Climate Change and Farmer's Perceptions. Articles were filtered using variations of the words "climate change," "farmer," and "perceptions." Vos Viewer was used to map the connections between the filtered articles and for the top 100 keywords mentioned at least five times across all articles. Larger dots indicate words that were mentioned more frequently. Colors connect the themes; yellow is sociological, red is methodological, green is agricultural, and blue is meteorological.

Climate Change Perceptions

Climate change perceptions have been studied through a multitude of disciplines such as environmental sociology, social psychology, science communication, meteorology, and biology (Norgaard et al. 2011). For instance, studies have shown that politics can influence perceptions of climate change (Dunlap and McCright 2012) The Reagan Administration, for example, influenced the climate change denial movement. President Reagan promised that the government would ease off the private sector. The Administration's efforts were challenged by environmental activists, the impact of which was a reduction in anti-environmental rhetoric. According to Dunlap and McCright (2012), this experience taught political conservatives that it was more effective to question environmental regulations by challenging evidence of environmental degradation, rather than environmental protection goals. Years later, the Clinton-Gore Administration's approach toward environmental protection (e.g. accelerated clean-up of toxic waste sites, protected national parks, ensured Americans have access to clean drinking water) heightened conservatives' regulatory fears (Dunlap and McCright 2012; The White House n.d.). This fear was further heightened with the creation of the Intergovernmental Panel on Climate Change (IPCC) and the World Meteorological Organization (WMO) (Dunlap and McCright 2012). The mainstream conservative movement teamed up with the fossil fuel industry to combat the economic threat posed by climate change. They believed that the fossil fuel industry would be heavily impacted. They also attacked climate science, rebranding it as "junk" and launched attacks on such pillars as the methods, evidence, and peer-review, as well as the associated institutions. The result was increasingly widespread environmental skepticism (Dunlap and McCright 2012). Funding from the fossil fuel industry, corporate America, and conservative foundations, along with the voices of contrarian scientists, contributed to conservative think

tanks and other front groups involved in climate change denial. Right-wing media and blogs, talk radio commentators, and politicians created “echo chambers” that attacked “environmental wackos,” climate change, and Al Gore (Dunlap and McCright 2012). Political events throughout history have influenced climate change perceptions to today, causing a split on whether climate change is real or not. In Alabama and the Southeast, these states are typically red, conservative, Republican states (Sugg and Weir 2023). For example, a study by Sugg and Weir showed that the 2016 and 2020 election results were an indicator of the acceptance of human-caused climate change in Republican-voting counties in the Southeastern United States (2023). In Alabama, this study classified the northern part of the state as a “group one” state, which consists of populations that have the lowest awareness, lowest risk perceptions, and most opposed to policies associated with climate change, The southern part of the state, on the other hand, is a “group 5,” which is indicative of moderate levels of acceptance, high risk perceptions, and high support for policies (Sugg and Weir 2023). This is due to the southern part of the state being more susceptible to extreme weather events including flooding and hurricanes. Group one counties are typically Republican counties and are closer to the Bible Belt. Overall, sociodemographics, politics, and regional variability differences can lead to differences in climate change perceptions in populations (Sugg and Weir 2023).

Studies of climate change perceptions among agricultural stakeholders in the US show that the risks are often seen as being distant and diffused over time (Haden et al. 2012; Church et al. 2017). Climate impacts that producers can see (e.g. warmer temperatures, runoff from extreme rain events) are perceived as concrete, tangible events. In contrast, global changes such as sea surface temperatures were found to be more difficult to perceive as it is not a tangible event (Haden et al. 2012). Previous studies (Haden et al. 2012; Church et al. 2017) find that

farmers and agricultural advisors are likely to believe that climate change is an ongoing natural process, but that humans do not cause it. These stakeholders are generally unconcerned about the impacts of climate change (Gramig et al. 2014; Church et al. 2017; Haden et al. 2012).

There are at least three gaps in the literature. First, there is the lacuna of longitudinal studies; studies of climate change perceptions are typically conducted at one point in time. These studies find, as mentioned above, that stakeholders are unconcerned about the impacts of climate change (Gramig et al. 2014; Church et al. 2017; Haden et al. 2012). Because these studies are not longitudinal, participants are not interviewed for differences in perceptions over time. Second, climate change perceptions are typically studied separately from weather perceptions; about 25% focus on meteorology or weather explicitly. Participants' use of weather terminology tends to emerge when asked questions about climate change, which suggests that weather and climate are closely connected (Ayanlade et al. 2017). This is to be expected as climate is a long-term weather impact and weather occurs in the short-term. When comparing qualitative data to biophysical data, investigators found that participants' perceptions aligned with meteorological data (e.g., rainfall, temperatures). For example, investigators who compared participant responses to a rainfall anomaly index (Ayanlade et al. 2017), average temperature, and precipitation levels (Reddy et al. 2022, Mbwambo et al. 2021) found that 60-70% of farmers could detect changes in the climate and that their perceptions were consistent with the empirical data. Finally, according to Norgaard (2011), many studies on climate change perceptions utilize individuals as their unit of analysis. The author states that there is a gap in studies that focus on how communities think and feel about climate change.

Perceptions of Climate Change Risk

Risk is the probability of an uncertain event happening combined with the incidental impact or negative consequence (Van Winsen et al. 2014). Studies of risk generally fall into two subcategories: risk perceptions and risk attitudes. Risk attitudes are complex as they involve a subject's orientation towards risk-taking (Van Winsen et al. 2014). Risk perceptions are composed of geographic, temporal, and social dimensions, along with feelings of uncertainty (Haden et al. 2012). Risk involves choices to act upon a risk and depends on risk assessments. For example, a producer may leave their peanuts in the ground longer to ensure they are grown enough for harvest. However, uncertainties in rainfall would need to be considered, as too much rainfall can harm peanuts. Too much moisture can lead to quicker rotting. Thus, producers are balancing risk (Van Winsen et al. 2014) and uncertainty daily. Daily variability in the weather and the return on technological investment are common uncertainties in production-based decision-making.

Climate change risk perceptions are influenced by gaps in knowledge. For example, Kari Norgaard (2011) describes the public's lack of information as a barrier in perceptions. Having access to accurate, easy-to-understand information can allow the public to form an informed perception. With a lack of information, perceptions may be inaccurate, as the public is forming an opinion with little knowledge to begin with. Norgaard, for instance, indicated that the degree to which the public responds to climate change is influenced by how well citizens understand climate change. The complexity of climate models limits the public understanding of climate change (Norgaard 2011). In her study, she found residents in her sample confused global warming and the ozone hole. People thought climate change came from the holes in the atmosphere solely. However, knowledge alone does not produce action because information in

the form of isolated “facts” does not have universal meaning across a community. Instead, information is socially structured and must be understood within a social context. Climate change “facts,” for instance, may be navigated and interpreted differently according to an individual’s sense of efficacy, self-esteem, and social support (Norgaard 2011).

In the context of agriculture, Bartels et al. (2012) conducted one of the few studies to take place in the Southeastern US. The authors found that values, beliefs, identities, goals, and social networks shape perceptions and knowledge about climate change. Importantly, if engagement processes to CDK ignore the socio-cultural context it will lead to less knowledge transfer (Bartels et al. 2012). Thus, producers and agricultural advisors would be less apt to become climate resilient. Collaborative stakeholder engagement processes are a “powerful social tool” for improving knowledge about climate change risks and strengthening adaptive capacities within rural communities.

The U.S. Department of Agriculture (USDA) Economic Research Service (ERS) (2023) identifies five categories of risk perceptions: price, production, financial, human and personal, and institutional. Price risk is the uncertainty about commodity prices, or the prices producers pay for inputs such as CSA. Production risk is the uncertain growth processes of crops, which would include the impacts of weather and climate. Financial risk is the chance producers take in borrowing money from lenders (e.g., CSA implementation), which could be subject to changing interest rates and restricted lines of credit. Personal risk arises from an individual’s personal life such as accidents, divorce, and deaths. Personal risks can arise from community interactions, as information or gossip can spread quickly in a neighborhood. Finally, institutional risks are uncertainties from potential government actions such as taxes and regulations that can make decisions more challenging. This risk, for example, can occur in states where producers have to

pay for water. The unpredictability of each type of risk can cloud judgment and make decision-making especially challenging (Tsiboe and Turner 2023).

Each category of risk perceptions can influence the adoption of CSA technology. If a farmer perceives the impacts from climate change, they may take steps to adopt CSA. For example, a study by Reddy et al. (2022) showed that 62% of farmers in their sample perceived the climate to be changing and wanted to protect their farms from the negative effects by crop diversification, contingency crop planning, and the development of crop-livestock systems. On the other hand, studies also show that producers may perceive climate change risks to be too distant and that it will not affect them in their lifetime. Wheeler and Lobley's (2021) study of how UK farmers experience and make sense of risk found producers who did not perceive adaptation as important to their farm due to the perceived uncertainties of risk. These farmers perceived adaptation as a waste of money due to the focus on short-term profitability and business survival. Technologies such as farm reservoirs, slurry lagoons, solar panels, and tree-planting are expensive to implement as infrastructure development is complex. The complexity of the technologies hindered producers' ability to visualize the long-term benefits of adoption. In some cases, technology adoption was driven by government incentives. For example, during Wheeler and Lobley's (2021) work, the UK was in the process of developing "grant aid," an incentive program, to provide farmers with funding to invest in technology such as on-farm water storage infrastructure and improvements to their soil health. However, when asked, farmers mentioned that due to present financial concerns, they would be more apt to focus on soil health improvements in 5-10 years, but their plans were vague and not designed with climate change in mind (Wheeler and Lobley 2021). In sum, incentives may encourage the adoption of tools and practices such as irrigation (Sydnor and Molnar 2020), crop diversification,

contingency crop planning, new or additional crop varieties (Reddy et al. 2022), and soil health plans (Wheeler and Lobley 2021).

Climate-Smart Agriculture

CSA is guided by three goals: to increase productivity, to enhance resilience, and to reduce emissions (USDA Climate Hubs n.db). Farming itself contributes to climate change. Greenhouse gases, for instance, are emitted from livestock, agricultural soil, and rice production (EPA 2024) and are thought to exacerbate climate change. CSA is believed to lessen this contribution by decreasing gases such as nitrous oxide (N2O), methane (CH4), and carbon dioxide (CO2). At the same time, farming is also affected by climate change, especially from rising temperatures and variability in precipitation. CSA tools and practices--conservation tillage, cover crops, nutrient management, irrigation scheduling--may combat these negative effects (USDA Climate Hubs n.db). The FOF project centers on variable-rate irrigation (VRI), cover crops, and nutrient management.

VRI is a conservation technology that enables a center-pivot irrigation system to optimize the use of water (Perry et al. n.d.). Farmers can use an automated method to vary rates of water based on management zones within a field. VRI is also more efficient. Withdrawals of water can be reduced as the exact amount of water needed is applied. Fields can have different topography and soil types, which means that certain parts may need more water than others. Irrigating every region of a field the same way could lead to overapplication of water. Thus, VRI helps to maintain well-watered crops by allowing producers to vary the amount of water put on different parts of a field. The choice to irrigate is a careful consideration of both price and production risk and weather information. VRI is useful in adapting water usage to weather conditions. For example, El Niño-Southern Oscillation (ENSO), is an ocean-atmospheric phenomenon that

affects sea surface temperature and causes warmer waters. In Alabama, El Niño causes wetter winters in the central and southern parts of the state and drier winters in the northern part. During an El Niño, summers are typically drier than normal except in the central part of the state (Woli et al. 2013). This variability makes efficient irrigation scheduling vital to preserve water supplies, especially during El Niño.

Sydnor and Molnar (2020), who conducted a study of Alabama producers in 2009, found the need for more information transfer and collective learning to better facilitate the transfer of irrigation technology. They suggest that community building would propel adoption by allowing producers to learn from each other (Sydnor and Molnar 2020). Their work promotes co-learning and illustrates a long-term gap in technology transfer within the state.

Cover crops such as grasses, small grains, and legumes, help preserve the soil; the soil is protected from meteorological phenomena including wind and rain that would otherwise cause erosion (Walia 2019). In addition to erosion control, cover crop root channels, and soil particles work together to absorb intense rain and improve water holding capacity (USDA Northeast Climate Hubs n.da). These crops also add organic matter to the soil, which helps crop growth even after cover crops are harvested. Studies suggest that cover crops will improve the long-term productivity of farmland (Walia 2019), while also providing at least some means of protection from weather and climate extremes.

The most prevalent barrier to cover crop adoption is the financial cost which includes seed, labor, and equipment (Duke et al. 2022). Many producers perceive cover crops to be a low return on investment due to the amount of labor and time it takes to plant them (Duke et al. 2022). Other barriers include education and information such as doubts about cover crop importance, and knowledge gaps. Studies find that these barriers can be mitigated by government

policies, education and Extension programming, and an increase in equipment availability. For example, both Ohio and Maryland provide federal cost-share through the Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP) (Duke et al. 2022). Maryland incentivizes cover crop adoption and use, while Ohio also covers best management practices beyond cover crops. According to Duke (2022), emphasizing cost-share initiatives during educational programs is vital in encouraging farmers to adopt conservation technology.

Finally, nutrients, including the use of nitrogen, chicken litter, and phosphate, are essential to crop growth. Benefits are maximized via the strategic use of the right fertilizer product at the right amount, from the right source, in the right place, and applied at the right time, which is often referred to as the "4R's" (Nehring and Mosheim 2020). Major rain events, for instance, can lead to nutrient runoff if applied in excess. Excess nutrients can be environmentally harmful; they can degrade water quality and create harmful algal blooms. Rainfall in Alabama is variable in both volume and timing of events, which adds to the complexity of making nutrient management decisions. Overall, there has been an above-average number of 3-inch extreme precipitation events since 1995 (Runkle et al. 2022). Major rainfall events can increase the likelihood of nutrient runoff and leaching into public water supplies.

There is much less literature on the adoption of nutrient management practices compared to VRI and cover crops. Most of this literature is specific to nitrogen management practices and the relationship between cover crops and irrigation. These studies are heavily focused on production in California (Khalsa et al. 2022, Rudnick et al. 2023). Barriers to the adoption of best practices in nutrient management have been found to include farm size (e.g., less than 20 hectares), access to irrigation systems, and low availability of information related to nutrient management practices. In one of the California studies, growers were found to adopt N+

practices more than irrigation and soil health (Khalsa et al. 2022). Growers with greater financial security, as well as large plots of land and access to microirrigation (e.g. low-pressure, low-rate irrigation) and water, tend to adopt nutrient management practices more often than their counterparts. The latter, having access to surface and groundwater, increases the adoption of conservation practices by 10-20% because of the demands of water in different CSA tools (Khalsa et al. 2022).

METHODS

The FOF aims to engage stakeholders in discussions about CSA, to demonstrate their effectiveness, and to provide adoption incentives. The focus of this sub-project is stakeholders' perceptions of weather and climate and how their perceptions influence the use of climate-smart technology.

Most CSA research is based on one-time surveys (e.g., Reddy et al. 2022), focus groups (e.g., Ayanlade 2017), and interviews (e.g., Sorvali et al. 2021); very few studies are longitudinal (e.g., Sorvali et al 2021, Makate and Makate 2022). In contrast, this thesis takes a longitudinal approach by analyzing two data sets collected between summer 2020 and fall 2023. Examining the same stakeholder groups may provide insight into how perceptions of climate change, weather, and economics may change over time.

As shown in Table 1, the first data set comes from a series of stakeholder events. The first three events were introductory meetings when the project first commenced. The remaining events (i.e., Field Days) revolved around a specific topic--nutrient management, irrigation, and cover crops. A specific activity of note was an irrigation scenario game that took place during the summer of 2021 (Table 1). Participants were given rainfall data for a specific period and asked to

decide how much to irrigate. Then, participants made predictions based on their previous decisions and the growth stage of the crop.

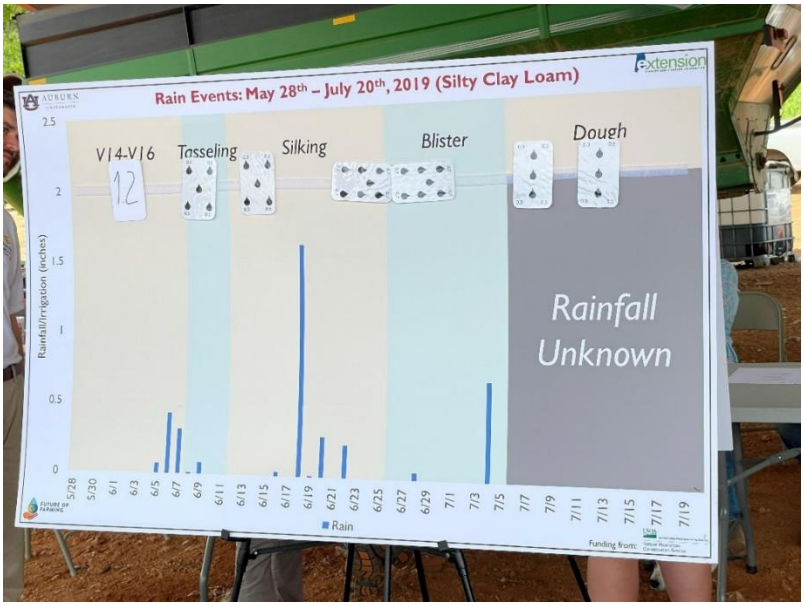

Figure 2: Decision Making Scenario Game at an Irrigation Field Day. Decisions that one team made during the June 3rd, 2021, Central Alabama Field day activity. Each card had a specific irrigation value on it, ranging up to 1 inch of irrigated water.

Attendance was taken at each event and included demographics such as name, role, address, email, phone number, gender, race, and birthday. To protect confidentiality, all participants were given a letter- and number-based pseudonym (#20-207 EX 2004). For reference purposes, F is for farmer, EA is for Extension agent, and CC is for crop consultant.

Table 1: Future of Farming Stakeholder Events.

Event	Date	Participants (total)	Participants[1] (types)	Length	Description
S AL Focus Group Meeting	9/24/20	n = 21	EA=2, ER=3, F=9, R=7	2:05:49	Discussion about barriers and limitations to adopting conservation strategies
N AL Focus Group Meeting	12/7/20	n = 21	CC=2, EA=4, ER=3, F=3, G=4, R=5	1:41:00	Discussion about barriers and limitations to adopting conservation strategies

Event	Date	Participants (total)	Participants[1] (types)	Length	Description
C AL Focus Group Meeting	12/9/20	n = 17	CC=1, EA=1, ER=3, F=5, G=1, R=6	4:00:00	Discussion about barriers and limitations to adopting conservation strategies
C AL Cover Crop Field Day	2/17/21	n = 25	CC=3, EA=2, ER=3, F=10, G=2, R=5	4:00:00	Introductions and explored cover crop demo sites
S AL Cover Crop Field Day	3/3/21	n = 23	EA=3, ER=5, F=8, G=2, R=5	4:00:00	Introductions and explored cover crop demo sites
N AL Cover Crop Field Day	3/8/21	n = 20	CC=2, EA=3, ER=4, F=5, G=1, R=5	4:00:00	Introductions and explored cover crop demo sites
C AL Irrigation Field Day	6/3/21	n = 25	EA=3, ER=1, F=4, G=3, R=14	4:15:00	Introductions and small groups discussed irrigation scenarios, followed by a debrief
S AL Irrigation Field Day	6/15/21	n = 22	EA=3, ER=4 F=3, G=3, R=9	3:30:00	Introductions and small groups discussed irrigation scenarios, followed by a debrief
N AL Irrigation Field Day	7/15/21	n = 27	CC=1, EA=3, ER=4, F=8, G=3, R=8	3:30:00	Introductions and small groups discussed irrigation scenarios, followed by a debrief
C AL Nutrient Mgt Field Day	12/2/21	n = 31	CC=4, EA=3, ER=7, F=7, G=2, R=8	4:00:00	Presentations from CCs and ERs and observations and ratings of chicken litter samples.
S AL Nutrient Mgt Field Day	12/9/21	n = 45	CC=3, EA=6, ER=3, F=24, G=2, R=7	4:00:00	Panel discussion with CCs and EAs
C AL Cover Crop Producers meeting	3/1/22	n=15	CC=2, EA=1, ER=3, F=3, R=6	1:10:00	Explored cover crops, discussions among participants in fields
S AL Cover Crop Producers meeting	3/16/22	n=13	CC=2, EA=1, ER=3, F=3, R=6	2:00:00	Explored cover crops, discussions among participants in fields

Event	Date	Participants (total)	Participants[1] (types)	Length	Description
N AL Irrigation Field Day	7/12/22	n=36	CC=4, EA=2, ER=2, F=4, G=5, R=17, O=1	3:00:00	Explored producers' fields, discussion of irrigation strategies at each site
S AL Irrigation Field Day	8/10/22	n=25	CC=1, EA=2, ER=2, F=11, G=1, R=8	1:30:00	Expert presentation, discussions among participants
S AL Nutrient Mgt Field Day	11/16/22	n=35	CC=3, EA=5, ER=2, F=12, G=1, R=8, O=6	1:32:00	Discussions among participants
C AL Nutrient Mgt Field Day	12/6/22	n=14	ER=2, F=2, G=1, R=8, O=1	1:57:07	Discussions among participants
S AL Cover Crop Producers meeting	3/10/23	n=36	F+R=1, EA=3, ER=2, F=8, G=4, R=11, O=6	3:45:00	Explored cover crop demo sites, farmer led discussions
S AL Irrigation Field Day	6/26/23	n=56	CC=5, R+O=1. F+G=2, F+O=2, EA=4, ER=2, F=9, G=9, R=10, O=10	4:00:00	Sustainability indicators game, discussions among participants
C AL Irrigation Field Day	7/19/23	n=47	ER+G=1. F+EA=1, F+R=1, EA=1, ER=2, F=10, G=9, R=13, O=9	3:30:00	Sustainability indicators game, discussions among participants
N AL Nutrient Management Field Day	11/27/23	n=40	ER=3, O=3, R=6, EA=6, G=6, CC=6, F=9, CC+G=1	2:30:00	Stakeholder nutrient management panel, discussions among participants
C AL Nutrient Management Field Day	12/7/23	n=19	ER=2, O=1, R=6, EA=2, G=2, CC=2, F=2, F+R=2	2:15:00	Stakeholder nutrient management panel, discussions among participants
S AL Nutrient Management Field Day	12/11/23	n=44	EA=2, ER=3, F=15,G=1, R=12, CC+F=1,	2:00:00	Stakeholder nutrient management panel, discussions among participants

Event	Date	Participants (total)	Participants[1] (types)	Length	Description
			F+G=1, CC=3, O=6		

[1] Crop Consultant = CC; Extension Field Agent = EA, Farmer = F, Government = G, Researchers = R, Extension Specialists = ER, Other = O

The second data set includes 83 interviews with participants including other researchers, producers (F), Extension Specialists, Extension agents (EA), crop consultants (CC), and government employees. For this analysis, 38 interviews were used including all producers (n=25), crop consultants (n=6), and Extension field agents (n=7) as they provided more detailed information about on-farm decision-making. Most interviews were part of a preexisting data set, conducted between fall 2020 and spring 2022 (Stewart 2022, Robinette 2022). Added to this data set were an additional 6 producer interviews that were conducted in October of 2022. This case study contributes to the research questions by examining how a major meteorological event, Hurricane Ian, can affect decision-making. Phone interviews and text communications with the producers took place when Alabama was in the "cone of uncertainty." In particular, these data show how information about extreme weather is perceived and how stakeholders claim to behave in response (i.e., precautions to be taken).

The case study interviews were based on a questionnaire. All participants were active members of the learning network, and they were contacted by phone and text which are common communication methods among this population. Six producers agreed to an interview, five in the Southern region and one in the Central region. This number was low as producers were in the midst of harvest. The guide included questions about irrigation and decision-making within the context of the pending storm, including: "What are your thoughts on the storm (e.g., worried, concerned, indifferent), "How might Ian change your decision-making over the next couple of days," and "What meteorological issues concern you the most about the storm (e.g., wind speeds,

rainfall, economics [damage], harvest)?" Interviews were conducted via phone and lasted about 15 minutes.

A specific activity of note was an irrigation scenario game that took place during the summer of 2021 (Table 1) Participants were given rainfall data for a specific period and asked to decide how much to irrigate. Then, participants made predictions based on their previous decisions and the growth stage of the crop.

All data—stakeholder events and interviews--were recorded, transcribed, and uploaded to NVivo 14 for coding and analysis. There were four steps in the coding process. First, text search queries were used to identify targeted words and phrases (Table 2). These queries were driven by the research questions, the peer-reviewed literature, the project themes/objectives, and the issues that emerged during the preliminary analysis process. These searches were saved as nodes. Technological keywords (n=22,134) were searched within the weather and socioeconomic codes, only.

Table 2: Source of Meteorological, Sociological, Economic, and Technological Keywords.

Topic	Source	Concepts	Related Keywords and Synonyms (Concept Dimensions)
Meteorological	Woli et al. (2013)	El Niño, La Niña	Rainfall, rain, climate, ENSO, showers
	Wang and Cai (2009)	Forecasting	Uncertainty, prediction, chance, forecast
	Ayanlade (2017)	Climate extremes, perceptions	Flood, drought, dry, rain, wind, weather, precipitation, meteorologist, meteorology, lightning
	Church (2017)	Climate change perceptions	Humid, extreme, warm, storm, heat, cool, fog, funnel

Topic	Source	Concepts	Related Keywords and Synonyms (Concept Dimensions)
	Mini Case study[2]	Extreme weather events decision making	Hurricane, runoff, disaster, weather station, tornado, evapotranspiration, hail, freeze, storm, thunderstorm, moisture, runoff, condensation, evapotranspiration, transpiration, breezy, cold, dew, drizzle, temperature
Technological	USDA Climate Hubs Wang and Cai (2009) Reddy (2022)	Climate-smart agriculture (CSA)	Productivity, emissions, conservation tillage, cover crops, nutrient management, irrigation scheduling, crops, varieties, contingency crop planning, soil health, practice, technology
	Personal Communication[1]	Climate-smart agriculture (CSA)	fertilizer, water, diesel, phosphorus, nitrogen, litter, rye, grain, oats, pump, wilt, nozzle, sprinkler, irrigation
Sociological	Wheeler and Lobley (2021) Wakweya (2023)	Resilience/Profitability	adaptation, adapt, extreme, adopt, implement, mitigation
	Van Winsen (2014)	Risk perceptions/risk attitudes	Uncertain, negative, consequence
	USDA ERS (2023)	Types of risk	Price, production, financial, human, personal, institutional
	Church (2017) Gramig (2013)	Climate change perceptions	Indifference, feeling, social, temporal, geographical
	Nowak (1987)	Adoption-diffusion theory	Transfer, tool, decision, challenge, liability, threat, menace, crisis, exposure
Economic	Wakweya (2023)	Adoption of CSA	Profit, money, cash, capital, demand, cost, benefit, expensive, income
	Church (2017)	Climate Change Perceptions	Insurance, price,
	Roesch-McNally (2017)	Cover crop barriers to adoption	Income, demand, likelihood

Topic	Source	Concepts	Related Keywords and Synonyms (Concept Dimensions)
	Personal Communication[1]	Economics	Analysis, expense, revenue, interest, supply, sales, inventory, inflation, debt, credit, budget, return

[1] Keywords and synonyms from personal communication with project personnel
[2] Keywords and synonyms from the mini case study conducted within this project

Second, the data was coded for both actor types (i.e., crop consultant, Extension agent, farmer) and project year (i.e., 2020, 2021, 2022, 2023). Within each year for producers, perceptions of the focal CSA tools and practices were identified and classified as positive, neutral, or negative sentiments. For example, if a producer complained about the expense of a technology, it would be classified as a negative sentiment. If a producer simply stated a fact, it was considered a neutral sentiment. If a producer complimented a technology or described how it is used to make their farm better, it was identified as a positive sentiment. Crop consultants (CC) and Extension agents (EA) were grouped together as there was limited data. These data make possible the identification of opportunities for, and barriers to, adoption.

Finally, a crosstabulation was used to assess the relationship between weather and climate perceptions and perceptions of CSA, the relationship between weather and climate perceptions and socioeconomic perceptions, and the relationship between socioeconomic perceptions and perceptions of CSA. These crosstabulations indicate how many times two sets of keywords were mentioned in the same group of sentences that were coded.

The findings are separated into two sections. The keyword analysis is an analysis of the individual codes, and the second section is the crosstabs between codes.

KEYWORD ANALYSIS

The following section will examine producers' and crop consultants' and Extension agents' (i.e. agricultural advisors') language during field days and interviews. These data

contributes to the research questions “How do stakeholders (i.e., producers, crop consultants, Extension agents) perceive weather and climate?” and “How do these perceptions influence the use of climate-smart technology?” This section begins by presenting the weather data, from all stakeholders, then focuses more specifically by looking at the top 10 words in each stakeholder group (i.e., producers and agricultural advisors). This structure is repeated in both the technology and socioeconomic sub-sections. A cross-tabulation of meteorological and technological, socioeconomic and technological, and meteorological and sociological words is examined in the section titled Crosstabulations.

Figure 3 shows the unique participants who spoke at least once during a field day or interview. “Agricultural advisors” is the combination of both crop consultants and Extension agents, which are grouped together due to the limited data from these two groups. The number of participants is relatively equal within each topic area, with more unique producers speaking about technology and more unique agricultural advisors focusing on meteorology.

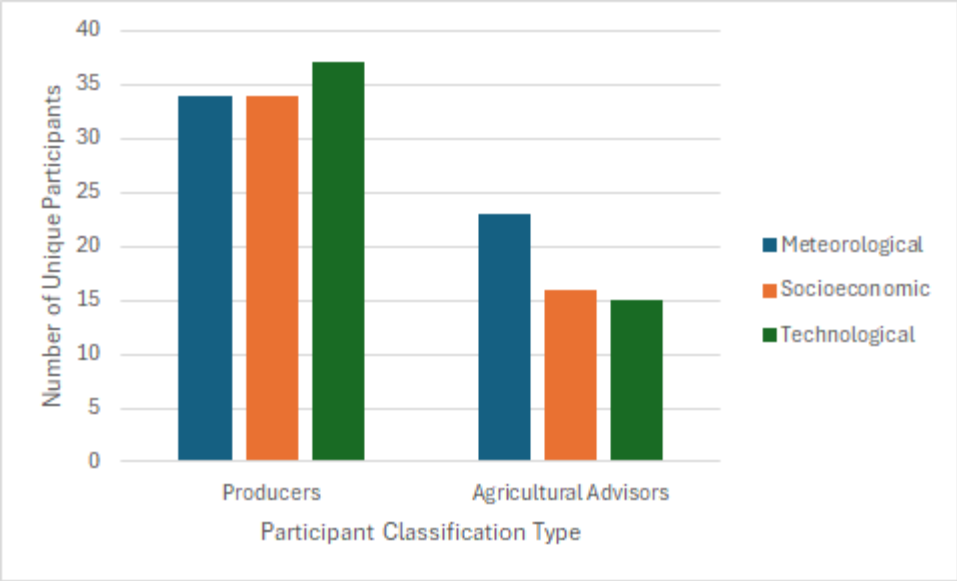

Figure 3: Participant Classification. Number of unique participants who mentioned each set of keywords at least one time.

Meteorological

All stakeholders. Figure 4 illustrates the most frequently mentioned meteorological words (n=2,832) by all participants during field days and interviews. Rain is the most used meteorological word (n=598). Moisture is mentioned 533 times, which is the second highest, but only 15.1% (n=81) of which came from producers and agricultural advisors. Moisture differs from rain in that it is used to refer to "sensors" or "soil" by nearly all stakeholders. Very few references are related to atmospheric moisture. Researchers, government officials, and Extension specialists promote the use of soil sensors and the importance of monitoring soil moisture when planting. These stakeholders speak frequently about "moisture sensors" in terms of usefulness (G4, ER3) and conservation (ER5, R2, R3).

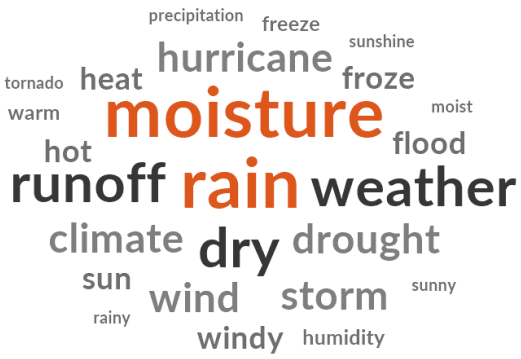

Figure 4: Meteorological Word Cloud of All Participants. The bigger the word, the more often it was used (n=2,832). The red words indicate the top two most mentioned keywords.

Producers and agricultural advisors. Mentions of weather phenomena were highest in 2021 for producers, while agricultural advisors spoke about weather most in 2021 and 2022 (Figure 5). These results are likely linked to the summer 2021 irrigation field day series described (see Methods). This field day will be described again in the crosstabulation section.

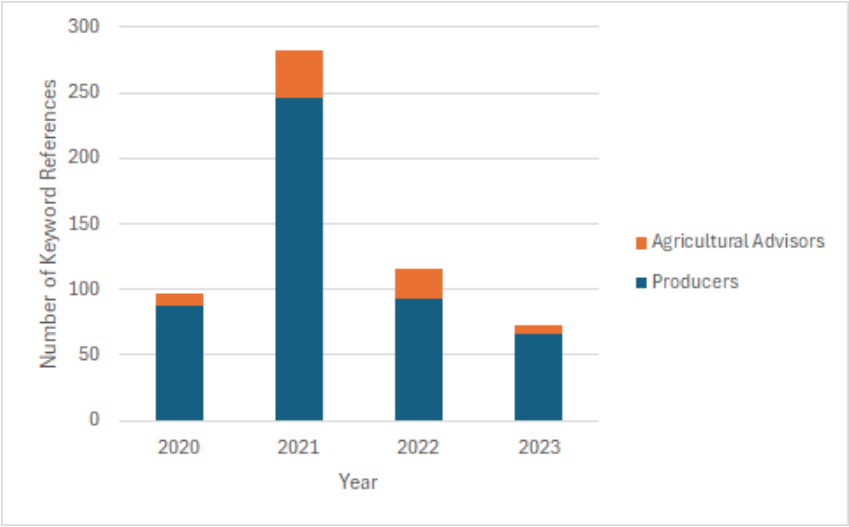

Figure 5: Number of Keyword References. The use of weather keywords, each year, by producers and agricultural advisors.

Figure 6 shows the word clouds for producers (A) and agricultural advisors (B). There were 488 mentions of the weather by producers and 85 mentions by agricultural advisors. Both stakeholder groups used dry, rain, and weather the most.

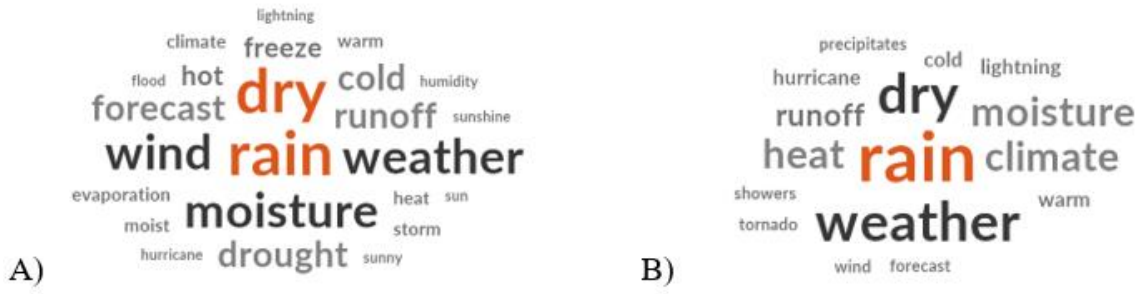

Figure 6: Word Clouds of the Meteorological Keywords. A represents producer use of keywords (n=34,488 mentions) and B represents agricultural advisor use of keywords (n=1,485 mentions). The bigger the word, the more often it is mentioned. The red words are the top 1 or 2 words mentioned, while the black bolded words are the next group that are mentioned most frequently.

The word "rain" oversaturates the overall dataset. Rain is the most frequently mentioned word among all stakeholder groups. Table 3 shows the top ten meteorological words spoken by producers and agricultural advisors. Producers perceive runoff and rain as related, and they assume that runoff happens due to significant amounts of water on a field from, for instance, a heavy rainfall event. The use of the word runoff tends to be associated with conservations about CSA, specifically nutrient management and cover crops. Fertilizer runoff is a concern of producers who recognize its potential to contaminate water supplies.

Wind is fifth; it is mentioned by producers (5.33%), but not used by agricultural advisors (n=1). In fact, the one advisor reference to wind was not about on-farm decision-making, but instead, focused on companies using solar wind for renewable energy. Producers cited varying issues related to the wind including pesticide drift (F15), erosion (F7, F11), and crops that blow away altogether (F2, F6, F14). The importance of wind poses a potential disconnect between the concerns of agricultural advisors and producers.

Table 3: Top Meteorological Keywords Mentioned During Field Days and Interviews by Producers and Agricultural Advisors. Bolded words indicate that it is from the top 10 in both the producer and agricultural advisor groups.

	2020		2021		2022		2023		Total %	
Keyword	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)
Rain, rained, raining, rains	29.89 (n=26)	20.00 (n=2)	34.96 (n=86)	43.24 (n=16)	33.33 (n=31)	18.90 (n=7)	25.76 (n=17)	42.86 (n=3)	32.79 (n=160)	30.12 (n=25)
Dried, dries, dry, drying	25.29 (n=22)	30.00 (n=3)	16.67 (n=41)	13.51 (n=5)	13.98 (n=13)	11.11 (n=4)	16.67 (n=11)	28.57 (n=2)	17.21 (n=84)	16.87 (n=14)
Moisture	10.34 (n=9)	30.00 (n=3)	14.63 (n=36)	5.41 (n=2)	9.68 (n=9)	16.67 (n=6)	21.21 (n=14)	14.29 (n=1)	15.16 (n=74)	8.43 (n=7)
Weather	12.64 (n=11)	20.00 (n=2)	9.35 (n=23)	8.11 (n=3)	17.20 (n=16)	8.33 (n=3)	9.09 (n=6)	0.00 (n=0)	11.27 (n=55)	9.64 (n=8)
Wind, winds	5.75 (n=5)	0.00 (n=0)	5.28 (n=13)	2.70 (n=1)	7.53 (n=7)	0.00 (n=0)	1.52 (n=1)	0.00 (n=0)	5.33 (n=26)	1.20 (n=1)
Runoff	2.30 (n=2)	0.00 (n=0)	5.28 (n=13)	0.00 (n=0)	0.00 (n=0)	11.11 (n=4)	0.00 (n=0)	0.00 (n=0)	3.07 (n=15)	4.82 (n=4)
Forecast, forecaster, forecasting, forecasts	0.00 (n=0)	0.00 (n=0)	4.07 (n=10)	2.70 (n=1)	5.38 (n=5)	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	2.46 (n=12)	1.20 (n=1)
Drought	1.15 (n=1)	0.00 (n=0)	2.44 (n=6)	0.00 (n=0)	1.08 (n=1)	0.00 (n=0)	3.03 (n=2)	0.00 (n=0)	2.05 (n=10)	0.00 (n=0)
Cold	0.00 (n=0)	0.00 (n=0)	0.41 (n=1)	0.00 (n=0)	0.00 (n=0)	5.56 (n=2)	9.09 (n=6)	0.00 (n=0)	1.43 (n=7)	2.41 (n=2)
Freeze, freezes	2.30 (n=2)	0.00 (n=0)	0.63 (n=2)	0.00 (n=0)	2.15 (n=2)	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	1.23 (n=6)	0.00 (n=0)
Climate	0.00 (n=0)	0.00 (n=0)	1.22 (n=3)	10.81 (n=4)	0.00 (n=0)	8.33 (n=3)	0.00 (n=0)	0.00 (n=0)	0.61 (n=3)	8.43 (n=7)
Heat	3.45 (n=3)	0.00 (n=0)	0.81 (n=2)	2.70 (n=1)	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	1.02 (n=5)	6.02 (n=5)
Hurricane	1.15 (n=1)	0.00 (n=0)	0.41 (n=1)	5.41 (n=2)	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	0.41 (n=2)	2.41 (n=2)
Warm	3.45 (n=3)	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	1.08 (n=1)	2.78 (n=1)	1.52 (n=1)	0.00 (n=0)	0.61 (n=3)	1.20 (n=1)
Total	100.00 (n=85)	100.00 (n=10)	100.00 (n=237)	100.00 (n=35)	100.00 (n=85)	100.00 (n=32)	100.00 (n=58)	100.00 (n=6)	100.00 (n=459)	100.00 (n=78)

Similar to all participants, producers and advisors typically mention moisture in reference to soil and monitors. The few times that moisture was used by agricultural advisors or producers were associated with weather events such as tropical moisture from a hurricane. For example, in discussing Hurricane Ian, one farmer (F8) expressed concern about increased tropical moisture that could defoliate their cotton. The words dry and drought are used differently. Dry was used 17.21% by producers and 16.87% by agricultural advisors. Drought was not mentioned by agricultural advisors but it was mentioned several times (2.05%) by producers. Agricultural stakeholders used the word drought to refer to extended periods without rain, while dry was used in different contexts. These contexts included soil being dry and cracked, and in some cases, the air itself was described as dry.

In examining the word "weather," producers mention it 55 times (11.27%) and agricultural advisors mention it 8 times (9.64%). Weather is used in two different contexts: what happened in a stakeholder's past (F18, F4, F28) or hypothetical scenarios that could positively or negatively affect a stakeholder (F11, F17, EA19). There are positive aspects of weather that producers do reference such as getting rain at a time that was needed; however, most perceptions of weather are negative and most discussions of weather focus on its negative effects on crops such as when to water, how much water is needed, and what to plant. Literature has shown that many producers are skeptical about climate change and long-term, negative, weather impacts due to it (Doll et al. 2017, Church et al. 2017). Producers and agricultural advisors alike tend to accept there are negative risks for agriculture in terms of weather but there is little concern for climate change (Church et al. 2017). For example, a study by Doll et al. indicated that many producers make reactive management decisions, those actions that are made after an event happens, but not proactive decisions, those actions that are made in preparation for an event

(Doll et al. 2017). If the climatic patterns benefit a producer, they will commend the weather for helping. As one producer (F5) stated:

> If [cover crops sit] in the rain you're gonna be picking peanuts . . . the reward is greater than the risk for us because if we don't and you miss that window . . . there's no telling when we may get hooked up and get to cover those seed up … it stayed dry only for six weeks and we were worried but as soon as it rained, [the peanuts] came out of it so we said you know for now on we're golden.

This perception is both positive and negative. The producer was worried about no rain, but when it finally did rain, it benefited them. For this producer, it is important to plant cover crops early, before they become too busy with harvest. Rain in this case was a benefit to the producer and the peanuts. This sentiment comes up from time-to-time, sometimes organically and other times when prompted to describe the positive impacts they saw on their farm. However there are potential risks of utilizing cover crops as they have the potential to absorb the available soil moisture.

The word climate was rarely used by producers (n=3, 0.61%) or agricultural advisors (n=7, 8.43%). When it was used, producers associated climate with climate change and referred to climate in that context. However, producers will also describe long-term changes such as rising temperatures and decreasing precipitation. Agricultural advisors, on the other hand, use the term climate when describing weather conditions over time, but not the phrase "climate change."

The word forecast is not utilized as often as expected. Some stakeholders mentioned that they do not rely on weather forecasts (F2, EA8), and instead depend on visual agroecological cues such as going out to the field to see the water level in person (F2). This perceived distrust in, and uncertainty of, weather forecasts is discussed in the next section.

With respect to words associated with temperature, stakeholders refer to cold and freeze in the context of it not being cold. For example, one producer (F80) said: “Went back to check my cover crops in early November… it hadn’t got cold enough to kill it (F80).” This producer is saying it was not cold to kill their crops which would be a good thing. There were very few mentions of low temperatures such as “We get a lot of really, really, cold weather” (F5). However, warm and heat are more likely to be mentioned. Producers used heat and warm interchangeably. For instance, they might claim that the temperatures are warm (F2, F14) or that heat is coming into the state (F15, F28). Warm was referenced only once by an Extension agent who referred to spring of 2022 as forecasted to be warm (EA19). Heat is not mentioned often, with one agricultural advisor using heat in terms of chemical reactions and noted how lightning can break the triple bond of nitrogen and create nitrates in the air. CC10 explained that where there is a combination of heat and pressure, more energy will be produced over time.

Technological

All stakeholders. Figure 7 illustrates the most frequently mentioned technological words by all participants during field days and interviews (n=22,134). Across these data, the word “crop” was used most frequently (n=3,923). Typically, crop was used in reference to cash crops, cover crops, or simply crops in a broad sense.

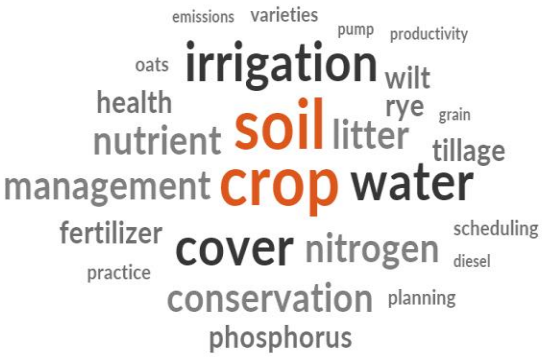

Figure 7: Technological Word Cloud of All Participants. The bigger the word, the more often it was said (n=22,134). The red words indicate the top two most mentioned technological keywords.

Producers and agricultural advisors. Figure 8 shows the number of times that producers and agricultural advisors mentioned technological words in each year. Producers were more likely to speak about CSA in 2021, while agricultural advisors were more likely to speak about CSA in 2020 and 2021. This result is due to the number of interviews conducted during these two years.

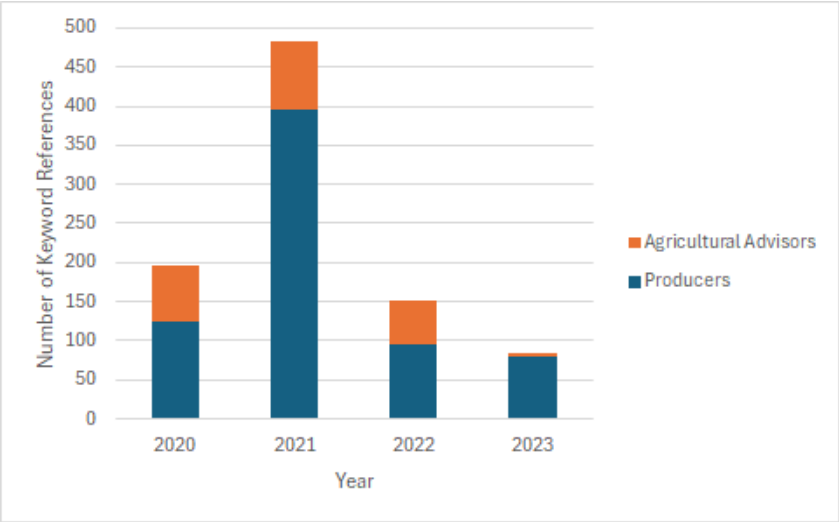

Figure 8: Number of Keyword References. Number of technological keywords that producers and agricultural advisors used each year.

Figure 9 illustrates words mentioned by producers (A) and agricultural advisors (B). Both stakeholder groups used the words crop and water the most. Crop is used in the same ways as all stakeholders with references to cash crops, cover crops, and simply crops in a broad sense.

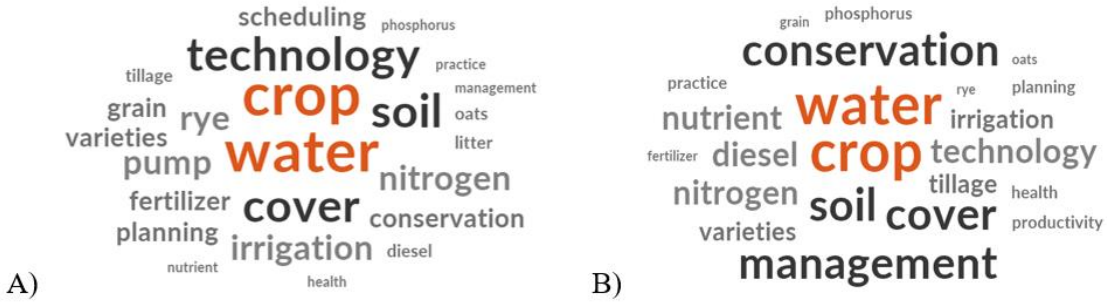

Figure 9: Word Clouds of the Technological Keywords. A represents producers' use of keywords (n=37, 729 mentions) and B represents agricultural advisors' use of keywords (n=15, 194 mentions). The bigger the word, the more often the word is mentioned. The red words are the top 1 or 2 words mentioned, while the black bolded words are the next group that are mentioned most frequently.

Table 4 shows the top ten technological keywords spoken by producers and agricultural advisors. Producers utilize CSA on their farms firsthand and refer to specific examples of CSAs more often. Agricultural advisors do not run farms and tend to advise on general management practices. For instance, looking at their top ten words, producers use three words refer to irrigation (i.e., water, irrigation, pump), two words refer to cover crops (i.e., cover, rye), two words refer to nutrient management (i.e., fertilizer, nitrogen), and two words fall into all three categories (i.e., soil, crop). In addition, the word technology was used broadly. In contrast, agricultural advisors tend to look beyond on-farm production to on-farm production to examine CSA issues on a broader scale (i.e. knowledge of multiple farms and what each is doing). Among the top ten technological words that advisors use, two relate to irrigation (i.e. diesel, water), one relates to cover crops (i.e. cover), two relate to nutrient management (i.e. nutrient, nitrogen), two relate to all three (i.e. crops, soil), and three words are more general (i.e. technology,

conservation, management). The variation in words indicates a difference in the type of language used. These results suggest that agricultural advisors may think more about inputs rather than the mechanics of production, while producers focus on specific tools and practices.

Table 4: Top Technological Keywords Mentioned During Field Days and Interviews by Producers and Agricultural Advisors. Bolded words indicate that it is from the Top 10 in both stakeholder groups.

	2020		2021		2022		2023		Total %	
Keyword	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)
Water	9.68 (n=12)	15.07 (n=11)	27.53 (n=101)	36.05 (n=31)	41.05 (n=39)	5.26 (n=3)	10.13 (n=8)	0.00 (n=0)	33.06 (n=241)	23.71 (n=46)
Crop, Crops	30.65 (n=38)	30.14 (n=22)	20.71 (n=82)	18.60 (n=16)	13.68 (n=13)	24.56 (n=14)	20.25 (n=16)	20.00 (n=1)	17.01 (n=124)	16.87 (n=14)
Cover	24.19 (n=30)	10.96 (n=8)	15.40 (n=61)	9.30 (n=8)	9.47 (n=9)	17.54 (n=10)	16.46 (n=13)	0.00 (n=0)	12.89 (n=94)	11.34 (n=22)
Soil	9.68 (n=12)	13.70 (n=10)	9.85 (n=39)	13.95 (n=12)	7.37 (n=7)	12.28 (n=7)	12.66 (n=10)	20.00 (n=1)	8.92 (n=65)	9.64 (n=8)
Technology	8.06 (n=10)	5.48 (n=4)	5.05 (n=20)	0.00 (n=0)	3.16 (n=3)	10.53 (n=6)	1.52 (n=1)	0.00 (n=0)	5.21 (n=38)	3.09 (n=6)
Irrigation	1.61 (n=2)	0.00 (n=0)	6.31 (n=25)	0.00 (n=0)	1.05 (n=1)	11.11 (n=4)	6.33 (n=5)	20.00 (n=1)	3.84 (n=28)	4.82 (n=4)
Rye	4.03 (n=5)	1.37 (n=1)	1.26 (n=5)	0.00 (n=0)	2.11 (n=2)	0.00 (n=0)	15.19 (n=12)	0.00 (n=0)	3.16 (n=23)	0.52 (n=1)
Nitrogen	0.00 (n=0)	0.00 (n=0)	2.52 (n=10)	1.16 (n=1)	3.16 (n=3)	5.26 (n=3)	6.33 (n=5)	20.00 (n=1)	2.61 (n=19)	2.06 (n=4)
Pump	0.00 (n=0)	0.00 (n=0)	0.25 (n=1)	0.00 (n=0)	8.42 (n=8)	0.00 (n=0)	1.27 (n=1)	0.00 (n=0)	2.61 (n=19)	0.00 (n=0)
Fertilizer	5.65 (n=7)	1.37 (n=1)	1.26 (n=5)	0.00 (n=0)	4.21 (n=4)	5.26 (n=3)	1.27 (n=1)	0.00 (n=0)	1.78 (n=13)	2.08 (n=4)
Conservation	0.81 (n=1)	4.11 (n=3)	3.54 (n=14)	2.33 (n=2)	0.00 (n=0)	3.51 (n=2)	0.00 (n=0)	0.00 (n=0)	1.65 (n=12)	3.61 (n=7)
Diesel	0.00 (n=0)	2.74 (n=2)	0.00 (n=0)	2.33 (n=2)	3.16 (n=3)	1.75 (n=1)	0.00 (n=0)	0.00 (n=0)	0.69 (n=5)	2.58 (n=5)
Management	0.00 (n=0)	4.11 (n=3)	0.76 (n=3)	3.49 (n=3)	0.00 (n=0)	3.51 (n=2)	0.00 (n=0)	0.00 (n=0)	0.55 (n=4)	3.61 (n=7)
Nutrient	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	4.65 (n=4)	1.05 (n=1)	0.00 (n=0)	1.27 (n=1)	0.00 (n=0)	0.41 (n=3)	2.06 (n=4)
Total	100.00 (n=117)	100.00 (n=65)	100.00 (n=356)	100.00 (n=79)	100.00 (n=93)	100.00 (n=55)	100.00 (n=73)	100.00 (n=4)	100.00 (n=631)	100.00 (n=132)

Water, irrigation, diesel, and pump are the most commonly mentioned words related to irrigation. Pumps are necessary to transport water and irrigate crops, and to power the pumps, diesel or electricity is required. Water is used in describing irrigation strategies (F28, F9, F11), rainfall (F38, F2), and water quality issues such as contamination of water for irrigation or personal use (F28). Many producers have a pond or lake from which they pump water. One producer mentioned topography was an issue in utilizing irrigation as it can affect how water is pumped from a source (F11). According to agricultural advisors (EA5), water is abundant in Alabama, but producers with varying topography can have trouble accessing it due to difficulties in moving water from the source (e.g. creek, pond) to the field. Topographic changes make water movement challenging as pumps need more energy and power to move water from the source to the final delivery point. In addition, producers who use water from ponds or creeks might have problems during drought conditions in the summer. Prolonged droughts might limit their ability to irrigate.

Knowledge barriers are an issue when it comes to irrigation (F28, F36). For example, one producer (F36) mentioned: “We’re doing a pretty good job with nitrogen and seeding . . . [but] I don't know enough about variable irrigation to know whether . . . the expected return . . . .” In contrast, to the knowledge gap about VRI, this producer was very vocal about their nutrient management and farming experience. Producers noted several knowledge gaps (e.g. not understanding how to schedule irrigation, what a “prescription” is) which could be a reason why irrigation is mentioned less frequently than cover crops.

Producers use different types and sources of nutrients to promote crop growth including phosphorous (F38), potassium (F38), and nitrogen (F22), and indicate that these nutrients are stored in the soil and aid future crop growth. For example, F54 said “I put 30 pounds of

ammonium N^+ on that first field . . . But we didn't put any at all on the rye grass, on the five acre-field where we had that vetch . . . it was just living off of the residual nitrogen from that vetch." This quote shows that at least some producers understand how cover crops can play a role in nutrient management, even after "burn down." In addition, discussion of nutrient management among stakeholders tends to elicit a wide range of language including acronyms such as "P" and "K" (F38).

Cover crops are the CSA that producers speak about most often. Different types of cover crops are used such as rye (F4, F2), triticale (F18), radish (F4, F12), and clover (F12). Cover crops were spoken about both positively and negatively. For example, one producer (F39) mentioned "rye comes out and it's not good . . . you still got the dying down, it takes all the moisture out." In this case, the concern was that rye affected the soil negatively by absorbing moisture that would otherwise be available to agronomic crops. On the other hand, a different producer (F54) said that they have "gotten the benefit of the rye grass . . . plus this rye grass on top of that," meaning there were to be two years of benefits. Agricultural advisors are more likely to use the phrase "cover crops" when speaking during the interviews. For instance, rye was only mentioned 1 time by agricultural advisors, while producers mentioned rye 23 times. Agricultural advisors think about cover crops more generally; they reference, for instance, concerns about the lack of cover crop usage such as leaching (CC9), as well as the best approaches to increase cover crop adoption. One advisor (EA5) stated that "cover crops [have] become an issue here as of late . . . [they are] something new to learn about [including] how to implement" them.

Socioeconomic

All stakeholders. Figure 10 illustrates the most frequently mentioned socioeconomic words by all participants during field days and interviews (n=4,270). Money is the most used socioeconomic word, with it being said 648 (15.17%) times by all stakeholders. Other socioeconomic words that are related to money include cost, benefit, and expense.

Figure* 10*: Socioeconomic Word Cloud of All Participants. The bigger the word, the more often it was used (n=4,270). The red words indicate the top three most mentioned keywords.

Producers and agricultural advisors. Like previous concepts, mentions of socioeconomic phenomena were highest in 2021 for producers, while agricultural advisors were highest in 2020 and 2021. Figure 11 shows the number of times that producers and agricultural advisors mentioned these words each year. Agricultural advisors tend to talk about socioeconomic topics more often than the other categories of keywords examined. This may show that socioeconomics, broadly speaking, is a more central concern to agricultural advisors compared to producers. Producers' use of these socioeconomic terms decreased in each year, showing that socioeconomics may not be the only driving factor in decision-making.

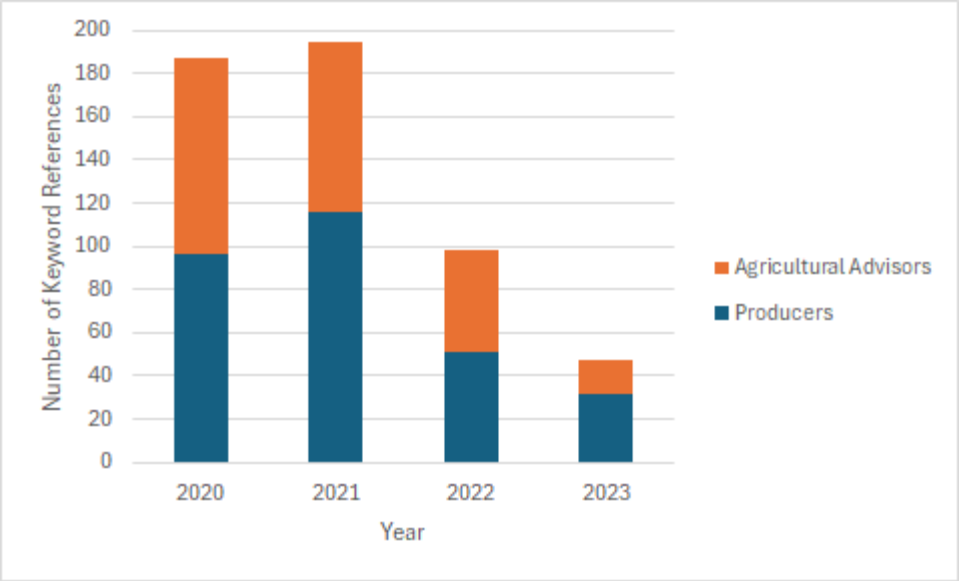

Figure 11: Number of Keyword References. The use of socioeconomic keywords each year by both stakeholder groups.

Figure 12 shows the word clouds for producers (A) and agricultural advisors (B). There were 300 mentions of various socioeconomic words among producers and 226 mentions among agricultural advisors. Both stakeholder groups mentioned cost and money the most.

Figure 12: Word Clouds of the Socioeconomic Keywords. A represents producers' use of keywords (n=34, 300 mentions) and B represents agricultural advisors' use of keywords (n=15, 226 mentions). The bigger the word, the more often the word is mentioned. The red words are the top 1 or 2 words mentioned, while the black bolded words are the next group that are mentioned most frequently.

Table 5 shows the top socioeconomic keywords spoken by producers and agricultural advisors. Both stakeholder groups used the same top four words.

Table 5: Top Socioeconomic Keywords Mentioned During Field Days and Interviews by Producers and Agricultural Advisors. The top socioeconomic keywords used by producers and agricultural advisors. Bolded words indicate that the word is from the Top 10 list in both stakeholder groups.

	2020		2021		2022		2023		Total %	
Keyword	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)	Prod (%)	Ext/ Cons (%)
Money	44.79 (n=43)	36.26 (n=33)	25.86 (n=30)	11.39 (n=9)	25.49 (n=13)	29.79 (n=14)	12.50 (n=4)	0.00 (n=0)	29.67 (n=89)	24.78 (n=56)
Cost	20.83 (n=20)	17.58 (n=16)	25.86 (n=30)	7.59 (n=6)	21.57 (n=11)	12.77 (n=6)	6.25 (n=2)	0.00 (n=0)	21.33 (n=64)	13.27 (n=30)
Benefit	8.33 (n=8)	3.30 (n=3)	14.66 (n=17)	18.99 (n=15)	7.84 (n=4)	8.51 (n=4)	12.50 (n=4)	13.33 (n=2)	11.33 (n=34)	10.18 (n=23)
Expense, Expensive	4.17 (n=4)	6.59 (n=6)	4.31 (n=5)	7.59 (n=6)	3.92 (n=2)	4.26 (n=2)	3.12 (n=1)	13.33 (n=2)	4.33 (n=13)	6.64 (n=15)
Implement	3.12 (n=3)	2.20 (n=2)	6.90 (n=8)	2.53 (n=2)	7.53 (n=7)	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	3.67 (n=11)	1.77 (n=4)
Credit, Credits	1.04 (n=1)	0.00 (n=0)	1.72 (n=2)	7.59 (n=6)	3.92 (n=2)	6.38 (n=3)	15.62 (n=5)	0.00 (n=0)	3.33 (n=10)	3.98 (n=9)
Payment, Payments	4.17 (n=4)	1.10 (n=1)	0.86 (n=1)	0.00 (n=0)	7.84 (n=4)	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	3.00 (n=9)	1.33 (n=3)
Cash	3.12 (n=3)	3.30 (n=3)	1.72 (n=2)	7.59 (n=6)	0.00 (n=0)	2.13 (n=1)	6.25 (n=2)	6.67 (n=1)	2.33 (n=7)	4.42 (n=10)
Budget	0.00 (n=0)	0.00 (n=0)	1.72 (n=2)	2.53 (n=2)	0.00 (n=0)	0.00 (n=0)	9.38 (n=3)	0.00 (n=0)	2.00 (n=6)	0.88 (n=2)
Decision	1.04 (n=1)	3.30 (n=3)	0.86 (n=1)	3.80 (n=3)	5.88 (n=3)	6.38 (n=3)	0.00 (n=0)	0.00 (n=0)	1.67 (n=5)	3.98 (n=9)
Demand	0.00 (n=0)	3.12 (n=3)	0.00 (n=0)	11.39 (n=9)	0.00 (n=0)	0.00 (n=0)	0.00 (n=0)	6.67 (n=1)	0.67 (n=2)	4.87 (n=11)
Supply	0.00 (n=0)	2.20 (n=2)	0.00 (n=0)	7.59 (n=6)	1.96 (n=1)	4.26 (n=2)	0.00 (n=0)	0.00 (n=0)	0.33 (n=1)	4.42 (n=10)
Total	100.00 (n=87)	100.00 (n=72)	100.00 (n=98)	100.00 (n=70)	100.00 (n=47)	100.00 (n=35)	100.00 (n=21)	100.00 (n=6)	100.00 (n=251)	100.00 (n=182)

Both groups focused on the economics of farming, versus the sociological aspects. The words implement and decision reflect social phenomena and they are related, but not interchangeable. A decision can be implemented through conservation practices. Implement is the action of going through with a decision, while a decision is a thought-out plan in a stakeholder's mind (Tiwani 2014). Nevertheless, the lack of sociological words shows the dominance of economics; it is a driving factor in decision-making.

Agricultural advisors use the words “supply” and “demand” more often than producers suggesting that advisors may think about complicated socioeconomic problems more broadly or in more formal terms. Cost, money, and expense are used interchangeably by producers. Producers seem to be more cognizant of the immediate on-farm economic effects such as cost, money, and expense. These effects are related to issues that affect their farms daily, versus supply and demand that affect wider markets. Producers perceive costs and expenses as a bit more controllable (e.g., minimizing costs, maximizing profit) in contrast to the global market price for a commodity that is completely out of their hands. Agricultural advisors take this a step further by not only referencing market, supply, and demand, but also focusing on how market events can affect the producers they work with.

CROSSTABULATIONS

This section presents the relationship between the use of socioeconomic and meteorological words, meteorological and technological words, and socioeconomic and technological words. These crosstabulations aim to understand how stakeholders’ perceptions might influence the use of climate-smart tools and practices.

Socioeconomic and Meteorological

There were very few mentions of both meteorological and socioeconomic words, implying that stakeholders do not specify socioeconomic issues related to weather and climate. There were 6 mentions of meteorological and sociological terms together for crop consultants, 3 mentions for Extension agents, and 22 mentions for farmers. However, a common theme emerged; participants focused on their perceived distrust and uncertainty about commercial weather forecasts. Previous studies have shown that forecast inaccuracies can influence user trust (Burgeno and Joslyn 2020; Vaughn et al. 2024). Though stakeholders look at weather forecasts

to see, for instance, the expected chances of precipitation and storm tracking, there is a general perceived distrust in these same forecasts. Producers, crop consultants, and Extension agents alike communicated that they believe the forecasts are unreliable and they will not make decisions based on them, solely. For example, F38 said:

> Well, I just tell you that a hundred times we sit in this building and watched it rain, the water runs out of the field on a hill . . . and we don't even get wet. I mean time after time . . . that's the reason we make it rain us out of the field if we're watering, we never [stop irrigating] because of a forecast unless it's a hurricane or something that [is] just a no brainer coming, you know what we'd call a rain event, rather than a summer thunderstorm, which is what we mainly live and die at.

Rain is a difficult phenomenon to forecast in specific geographic scales. It is very hard to pin down a forecast for one exact location. Pop-up showers, for instance, are brief events that can occur even if the skies are clear, and it is not forecasted to rain. These unexpected showers form as the ground is heated by the sun and can occur anywhere. In areas where heating has increased, warm air rises quickly to form an updraft. The quicker the air rises, the more likely a cumulus cloud will form. Pop-up showers are especially difficult to forecast due to the uneven heating. Portions of the ground that warm up quicker will create lighter air that rises quickly (DiPasquale 2022). One factor in uneven heating is albedo, which is the reflectivity of a surface; darker-colored land absorbs more sunlight and becomes warmer, while lighter-colored land reflects sunlight staying relatively cooler. In addition, there is a general perceived distrust of commercial weather companies. Perceived distrust in these companies can lead to potential perceived distrust in the forecasts themselves. For example, F2 said:

> One of the issues . . . that my guys and I discussed a few days ago is I think Weather Channel [and] Weather Underground . . . tend to mislead people to keep people tuning in to their coverage . . . I hate to say they give us misinformation like that . . . [Meteorologists] go and get a better idea on where [hurricanes are] gonna go a lot earlier than [the forecasts] they give here.

Producers indicated they trust hurricane forecasts more than daily weather forecasts; hurricane forecasts are perceived to be more reliable. Within a few days of impact, the forecasted track of a hurricane is fairly accurate due to the models' ability to incorporate the environmental factors (e.g., surface water temperature of the Gulf of Mexico) that drive storm strength and direction. Thus, producers know a few days in advance where and when to expect a hurricane and have an opportunity to prepare accordingly. Studies have shown that producers and agricultural advisors tend to make short-term changes when a hurricane is predicted, which aligns with the FOF participants. For example, Wiener et al. (2020) showed that advisors in the timber industry focus on short-term planning and recovery actions over long-term adaptation. These short-term techniques included moving equipment, removing harvested wood from the land, and stocking fuel for the generator. Similar strategies are utilized by FOF producers such as harvesting peanuts if appropriate or leaving them in the ground if there is not enough time to harvest safely, and moving irrigation equipment if damaging wind is forecasted.

Climate change has caused an increase in hurricane intensity over the years. This can potentially lead to increased rainfall events on producers' farms due to hurricanes being larger in size and more intense. However, many stakeholders indicate that they perceive climate change to be a hoax. According to F26, the Alabama state climatologist does not agree with the predominant thinking about climate change, thus they do not believe it either. As the producer

stated, “Well my personal opinion, I don’t think it’s really an issue. I think we go in cycles anyway.” The few who mentioned that they do believe in climate change indicated that they will only speak about it to the research team due to potential backlash from their neighbors. At the same time, producers will mention changes they have seen on their farms over the years such as temperature increases and changes in precipitation, but not attribute it to being human-caused phenomenon or use the phrase “climate change.” Other studies find that some agricultural stakeholders utilize language that illustrates climate change as an ongoing natural process, but do not see it as a human-caused phenomenon (Haden et al. 2012; Church et al. 2017).

Meteorological and Technological

Table 6 shows the crosstabulation of meteorological and technological words. There are more mentions of both meteorological and technological words among crop consultants and Extension agents than producers. Overall, stakeholders have both positive and negative accounts of how they use weather in making technological decisions. Producers make decisions in several different ways for several different types of technology. In this section, a discussion of irrigation, cover crops, and nutrient management decisions will be discussed.

Table 6: Crosstabulation Results of Key Concepts. The number of times that the two categories of keywords were mentioned in the same code. The first three percentages are in relation to the meteorological dataset and the last three percentages are in relation to the socioeconomic dataset.

	Meteorological			Socioeconomic		
Technological	Crop Consultants (n=29)	Extension Agents (n=54)	Producers (n=488)	Crop Consultants (n=96)	Extension Agents (n=130)	Producers (n=300)
Crop Consultant (n=75)	58.62% (n=17)			19.79% (n=19)		
Extension Agents (n=119)		44.44% (n=24)			26.92% (n=35)	
Producers (n=729)			28.2% (n=138)			32.33% (n=97)

Irrigation. Crop growth is highly dependent on the relationship between its stage of development and access to adequate water. Thus, producers tend to make decisions to irrigate depending on how much precipitation has occurred and is forecasted to occur, even though they do not trust the daily weather forecast. In other words, producers use the forecasts to give them an idea of what may happen but do not make decisions based solely on the forecast. The crosstabulation of technological and meteorological finds that rain was 19.56% (n=27) of mentions, while versions of dry were 13.04% (n=18) of producer mentions. This result suggests that rain may be a driving factor in when to utilize irrigation technology. Too little rain leads to drought-like conditions and subsequent dry soil; water from a source such as irrigation would be needed to replenish soil moisture. Soil probes and weather stations can be used in tandem to monitor the amount of moisture in the ground, and producers can use this information to determine how much water to use during irrigation. For example, F36 said, "So if I get an inch of rain, I'm good for about three days and then I'll start looking for water again." This producer's irrigation decision is based on present conditions. Some stakeholders communicated that they use radar more than long-term forecasts (EA8, F30). Radar data shows producers the near future--where current precipitation is and its general direction--which provides information about when to turn off the irrigation. Thus, while producers tend to use past experiences as a baseline, near-future conditions (e.g. radar) provide information about what will happen shortly, rather than the expected long-term future (e.g. 7-day forecasts).

In 2021, there were more meteorological and technological references due to the field day scenario game (see Methods). In terms of meteorological mentions by producers, 60.16% (n=148) were from the three irrigation meetings. During the scenario game, stakeholders used several factors in their decision-making including soil moisture (F33) and the previous amount of

water that the crops received (F4). The game illustrated that producers understand that more irrigation is necessary for crop growth in periods of low rainfall, especially during some stages of crop development. The game also illustrates temporal consideration when making irrigation decisions.

Agricultural advisors communicated that Alabama is one of the top states in terms of water availability (EA5), but water can be expensive for smaller farms (EA3) due to the costs of acquisition. Expenses will be discussed further in the next section. Expenses are balanced with proper conservation management. During the summer, there are increased droughts, which decreases water supplies. Crop consultants and Extension agents consider water management strategies when advising producers. For example, CC4 said, “A conservation effort that is not normally tagged as such, but it has to do with the water management . . . is getting the water off of the ground properly and not having ponding issues.” Ponding is an issue that also arises from increased precipitation events. Too much precipitation can lead to ponding on the ground and impact the CSA system, such as runoff of nutrients or increased soil moisture.

Some agricultural advisors tend to speak about CSA tools as one interconnected system unless specifically asked about a single tool or practice. For example, EA5 connected cover crops and irrigation specifically, stating “The system, . . . the cover crops, good water management, all that . . . nicely formed together into one thing. You don't just need to do it you know one side and one way it all needs to . . . come together and work itself out.” Other studies have also illustrated the relationship between CSA tools and practices. For example, Khalsa (2022) found that a barrier to adopting best nutrient management practices is irrigation use and access to water.

Cover Crops. Many producers mentioned that the cover crops help make their land more resilient to changing weather patterns. For example, F12 said, "We've had so much rain the last three weeks … we've seen water in places on our land that we've never seen before you know some of these no-till fields are not gonna hold up to all this . . . but if you got a cover crop on it helps." Cover crops help to retain moisture from extreme rainfall and reduce runoff and ponding. In addition, cover crops have helped producers to adapt to increased, storm-related, wind speeds. Many farmers mentioned that cover crops keep the soil in place (F6). Cover crops, however, are planted during the non-growing season, in the winter and spring. During the growing season, hurricanes and strong storms are more likely, which makes crops more susceptible to wind damage. Thus, cover crops serve as a climate resilience tool by not only holding the soil in place but also protecting it from erosion. Bergtold's (2017) work expands on this finding, indicating that cover crops help producers achieve sustainability and reduce negative environmental effects by also mitigating chemical runoff.

However, cover crops also present a management challenge. Many producers worry about the short-time frame between harvest season and winter to plant cover crops. The time frame is short because producers harvest crops in the fall, but also need to get cover crops planted in the fall so that there is enough time for them to grow properly and harvest them in enough time to get the next season's seeds planted. There also needs to be time for producers to allow the ground to dry out. For example, F28 said, "You gotta let it dry [which delays] planting on these farms . . . so it's a catch 22 because you're having a cover there to hold moisture." This is an example of a producer that decided to use CSA yet perceived it to be equally problematic as not using it. F28 acknowledged a tension between the reward of having cover crops holding moisture and the risk of those same cover crops taking moisture away from the soil.

Agricultural advisors also refer to cover crops as a climate resilience tool that includes moisture retention (CC4) and reduced tillage (EA19). For example, EA19 said, “Not knowing . . . what the climate's going to be this year in terms of [whether it’s] going to be really warm spring, really dry spring, are we going to be cool and wet, you know, having the cover crops, having that reduced tillage, is going to buy time.” This Extension agent believes that cover crops aid in reducing tillage and in maintaining soil moisture, which can reduce production risk from inclement weather.

Nutrient Management. Producers assumed runoff is the result of significant events like heavy rainfall or topographical differences. Runoff from rain may cause nutrients or fertilizers to be transported into water supplies or onto other farms, which can negatively affect the environment (e.g., leaches into water supplies, water quality issues). For example, F2 said, “Just depending on the soil and what . . . the weather's doing . . . we're spoonfeeding that corn slowly through the whole entire year. . . . the goal is for that corn to never lack nitrogen.” This quote signifies how the balance between nutrient application and meteorological conditions can be a challenge. Yet, by applying a small quantity at a time, F2 reduces the chances of fertilizer runoff. This example aligns with nutrient management studies (e.g., Nehring and Mosheim 2020) that point to the importance of “4R’s”: using the *right* fertilizer product at the *right* amount, from the *right* source, in the *right* place, and applying at the *right* time.

In terms of agricultural advisors, there are fewer mentions of nutrient management strategies compared to variable rate irrigation and cover crops. A search for nutrients--phosphorus, potassium, nitrogen--within the crosstabulations yielded only one result among crop consultants and one result among Extension agents. CC9, who was prompted to speak about the consequences of misusing fertilizer, referred to losing phosphorus in terms of leaching and

runoff. He was concerned that using too much fertilizer at once could lead to phosphorus runoff, thus wasting producers' time and money. EA6, on the other hand, referred to nutrient management in terms of the role of cover crops, which can serve as a filtration mechanism. The lack of nutrient management data among agricultural advisors might reflect a substantive area in which there is infrequent advising.

Socioeconomic and Technological

The results of the socioeconomic and technological crosstabulation (Table 6) show that producers are more likely to talk about socioeconomic issues associated with technology than the combination of meteorology and technology. Agricultural advisors spoke less about these same issues. Overall, both producers and agricultural advisors were favorable toward the technology as it does help the environment but raised concerns about the costs.

More than half (50.51%) of producers refer to either cost or money when discussing the socioeconomics of CSA. Costs of the various CSA tools on this project include but are not limited to, the cover crop seeds (F12, F28, F25, F2), the time necessary to implement practices (F11, EA3), the price of nitrogen (F22), the equipment (F22, F12), and the fertilizer (F11, CC9). For example, F12 mentioned "some of its probably timing . . . everybody's pretty much the same situation [as] they don't have a whole lot of labor; … they don't have that window left . . . to mess with the cover crop. I think the biggest problem with it is cost." As previously shown, cover crops were commended for helping farms become more climate resilient, but time and labor are inherent costs that create a barrier to cover crop adoption. Previous studies identified the same costs--cover crop seeds, planting, managing, and equipment--as barriers to CSA adoption (e.g. Duke et al. 2022). The work of Bergold et al. (2017) also points to the indirect costs such as the effects on cash-crop management, as well as foregone opportunities.

If a producer perceives a profitable harvest, data suggest that they may be more likely to use CSA. For example, one producer (F11) said: “You know, for $8 corn, I'll probably pull the plug on turning on the water. Whether they were predicting the rain two days away or not. But I might not be so quick for $3 corn. I might wait to see what the two-day forecasters are predicting . . . ” This quote is an example of a producer combining weather forecasting and crop price to decide on irrigation. During periods of high crop prices, a producer may decide to invest in irrigation. The example also shows a technological decision that takes into account both biophysical and socioeconomic aspects. F28 mentioned an information or knowledge barrier to VRI adoption stating, “maybe this is me just kind of being a bit ignorant . . . I don’t see the purpose, I don’t see a lot of benefit you know about variable rate irrigation.” This quote shows a producer not visualizing the longer-term economic and environmental benefits that VRI might bring. Irrigation field days have focused on general irrigation strategies and scheduling because VRI is expensive in terms of money and technological knowledge. The first hurdle is to get producers to adopt irrigation in general before moving on to VRI. There were seven irrigation field days examined in this thesis. During the 2022 irrigation field days, participants went to various farms and discussed with producers their irrigation strategies. This helped to increase CDK about irrigation scheduling strategies. In 2023, the field day was broad, with discussions about sustainability indicators and how they can be used on farms. Sydnor and Molnar’s (2020) 2009 study not only noted that producers need more information about irrigation, but also collective learning to better facilitate the transfer of irrigation technology, which field days in this project have helped to increase information transfer.

In many cases, producers have difficulty seeing future benefits to continued use of CSA. Agricultural advisors note that producers have a hard time comprehending the long-term benefits

of other technologies, as well. For example, in reference to cover crops, CC4 stated, ". . . very rarely do you ever see an instantaneous benefit that you may from erosion standpoint but as far as changing your soil structure it's a long horizon." Advisors understand that utilizing CSA technology is a long-term venture that will not give producers instantaneous benefits.

Agricultural advisors also expressed the need to be sensitive in their communication about economic costs, especially in the long-run costs of CSA. EA3 claimed they "put an emphasis on the cost of that tractor and how conservation tillage is saving that tractor." This Extension agent explained that they talk about cost saving in terms of relevant on-farm products and not with vague or random numbers. According to EA3, the adoption of conservation tillage would double the life of a tractor (i.e., from 7 years to 14 years). Moreover, the producer would not only save money on the tractor but also on the otherwise needed labor and diesel fuel to operate the tractor.

LIMITATIONS

There are several limitations that impact this study. Far more row crop producers are the state beyond those who are associated with the FOF project. Thus, the results may not be generalizable to the wider row crop population in Alabama or the Southeastern United States. Second, the number of attendees at the field day meetings was generally low due to schedule conflicts. Co-development and co-learning are a long-term undertaking that requires consistent participation from all stakeholders. North Alabama has had the least number of meetings, which means that the findings are skewed toward producers and advisors in south and central Alabama. Third, 2022 and 2023 had far fewer interviews which may impact the longitudinal results, particularly with respect to understanding how perceptions may have changed among Learning Group participants. No interviews were conducted with agricultural advisors since 2021 and only

six interviews for producers were conducted in 2022. Finally, it is likely that there are more keywords that could be searched (e.g., erosion, “P,” “K”). The keyword list created for the project does not entail all possible words and word substitutes that could have been used in relevant conversations.

CONCLUSION

The purpose of this project was to examine producer and agricultural advisors’ (i.e., Extension agents, crop consultants) perceptions of weather and climate and the potential influence of these perceptions on the use of CSA. Data from interviews and field days were used to examine three categories of keywords that align with meteorology, socioeconomics, and the relevant tools and practices (i.e. VRI, cover crops). Knowing how producers and agricultural advisors perceive weather and climate, and how they might respond with respect to CSA adoption, can help research and Extension teams create events that better serve the needs of agricultural stakeholders and work with stakeholders to develop more useful CSA. Climate-smart tools and practices are vital in adapting to changing environmental conditions and increasing producers’ climate resilience. This study is important to the meteorological community for at least two reasons. Knowledge of stakeholder perceptions illustrates what and where better communication skills may be needed within the meteorological community. Additionally, these findings provide clues about how to help a stakeholder group that has received little attention within the meteorological literature. This study is also important to the rural sociology community as it contributes to the extensive literature regarding CDK in agriculture and provides insight into how stakeholders think about complex agricultural problems.

Perceptions of Weather and Climate

The first research question asked, “how do stakeholders perceive weather and climate?” Perceptions among all stakeholders tend to be more negative toward weather and climate. Negative perceptions included discussions of how weather interferes with crops (i.e. too much or too little rain that damages crops, too much wind that leads to erosion), and uncertainties about weather information and effects (i.e. a weather forecast shows it will rain but it does not actually rain). Of the few positive perceptions, they are more likely to focus on instances in which the weather aided crop growth (i.e. rain that was desperately needed after a drought). Weather is perceived to be unpredictable and, in a field where a producer’s business can be heavily affected, there are day-to-day uncertainties (i.e. whether it will rain on a farm or not, how much rain will occur). Most producers and agricultural advisors communicated distrust in the forecasts, yet also claimed that they still use forecasts to aid in CSA decision-making. For instance, irrigation tends to be timed according to the amount of precipitation forecasted. Precipitation can affect when crops are planted as the best time to plant is when the soil is not overly saturated. Nutrient decisions tend to be timed during periods of little rain to decrease the chance of fertilizer runoff. Previous studies have not recognized the uncertainty and perceived distrust in weather forecasts, but rather the crop models that utilize weather forecasts (Tarraf et al. 2024) and the economic uncertainties in crops (Spicka 2011).

With respect to the climate, producers will describe long-term changes on their farms--increased rainfall, higher temperatures--but do not attribute these phenomena to “climate change” itself. Instead, the process is simply “just a cycle.” Agricultural advisors and producers typically do not use the phrase climate change, and many do not acknowledge that it may be real. Nevertheless, most peer-reviewed studies and scientific organizations acknowledge that both

global temperatures (IPCC 2021) and hurricane intensity (Knutson 2024) have increased. The latter is especially relevant to this study as many FOF participants are located relatively close to the Gulf of Mexico, and they have had personal experience with extreme rainfall and high winds, as well as subsequent crop damage, which is commonly associated with hurricanes.

Findings from this study suggest that weather information must be communicated to the agriculture community on a localized level. In addition, discussion of weather and climate including forecasting should be at the forefront of more Extension events. Bartels et al. (2012) conducted climate and weather adaptation workshops in the Southeastern US With row crop producers and other community stakeholders. These workshops helped to increase meteorological knowledge, while also increasing the CDK about climate adaptation (Bartels et al. 2012). One FOF project goal is to develop a learning network, which helps to build community and to increase CDK. Field days bring communities together to share knowledge about the challenges producers face on a day-to-day basis and to interact with one another. Thus, this learning network aids in learning about and shaping stakeholder perceptions. But, there was only one set of field days aimed at using meteorological information to make effective agricultural decisions. This discussion was imperative to the CDK process, as it allowed stakeholders to collaborate on irrigation scheduling decisions. This thesis, as well as previous literature, has shown that effective communication about weather information is linked to better management decisions (Church et al. 2017). Global weather and climate information is harder for stakeholders to understand because of a lack of site specificity (Haden et al. 2012).

Norgaard (2011) shows information discrepancies and knowledge gaps can lead to misunderstandings about the contributions of climate change, and to negative perceptions about climate change impacts. The author also found that the degree to which the public responds to

climate change is influenced by how well citizens understand the associated concepts and impacts. The complexity of climate models, for instance, and poor communication has led to misunderstandings (Norgaard 2011). While the FOF project is focused on decreasing knowledge gaps concerning specific CSA tools and practices, to date it has not fully addressed the influence of weather and climate on Alabama row crop production. While knowing how to use CSA technology is important, it is also important to know when best to utilize the technology. Attention to topics such as the interpretation of weather forecasts, the source of weather information, and the meaning of key meteorological concepts may further decrease CSA knowledge gaps and help producers in their decisions to adopt and to utilize CSA more effectively. In addition, there are gaps in the literature pertaining to climate change perceptions (Norgaard 2011).

Influence of Weather and Perceptions on the Use of Climate-Smart Agriculture

The second question asked, "how does weather influence the use of climate-smart technology?" Producers were found to weigh risks such as meteorological conditions and costs in their decisions to use CSA. They decide what will "buy them time (EA19)" from the effects of climate change, while also balancing current issues such as profitability. Weather is one factor that influences these decisions. For example, decreased rainfall may warrant the use of irrigation to assist in replenishing water necessary for crop growth and to adopt VRI to manage water scarcity. In contrast, increased rainfall could lead to fertilizer runoff, especially during extreme rainfall events. Cover crops help to absorb some moisture and reduce runoff. Similarly, high wind speeds can cause erosion in the absence of cover crops. Previous studies show that weather is one of the major factors in making decisions about the adoption and use of climate-smart technologies (e.g., Chen et al. 2021; Wang and Cai 2009). For example, Reddy et al. (2022)

found that producers who see climate change impacts are more apt to make decisions to adopt CSA. This thesis also illustrates how production, price, and financial risks (USDA ERS 2023) are balanced in FOF producers' decision-making; on-farm decisions are a multi-faceted issue. Producers and agricultural advisors speak about production risks such as weather concurrently with the financial and price concerns associated with CSA. Producers and agricultural advisors must balance various risks in ensuring business survival.

Beyond the weather, other influential factors associated with CSA adoption include economics (e.g., Khalsa et al. 2022; Duke et al. 2022; Reddy et al. 2022). Producers aim to utilize CSA in a way that will produce the most benefit for the least amount of cost. Some CSA costs include cover crop seeds and the time to implement the various practices, in addition to more traditional production expenses such as equipment and fertilizer (Roesch-McNally et al. 2018). For example, Duke et al. (2022) found that the most prevalent barriers to cover crop adoption were equipment, seed, and labor costs. A similar result was found in this thesis; diesel and cover crop seeds were in the top ten keyword hits. Future studies need to show producers both short and long-term return on investments as many CSA tools are not likely to reduce current expenses but become increasingly beneficial over time.

In addition to economic barriers to CSA adoption, Strategic choices in language may help in illustrate how CSA can be beneficial in both the short- and long-term. Perhaps more importantly, more effective communication strategies can help increase knowledge by showing agricultural stakeholders how CSA is part of an interconnected production system. Utilizing multiple CSA tools may be able to help farms in the environmental and economic sense. For example, irrigation can help increase soil moisture when there is not enough rainfall at the right time, whereas cover crops may help to hold some moisture in the soil and increase biomass

which is needed to improve soil health. Cover crops can also help protect the soil from erosion, and reduce runoff, which may occur from intense rain events. Thus, while each CSA tool has a specific purpose, they are more powerful when used together.

Findings also show inconsistent language between the two stakeholder groups. For example, agricultural advisors reference supply and demand more whereas producers were more likely to reference return on investment, which illustrates a difference in focus. Producers concentrate on their own farm whereas advisors focus on the broader industry and market. Differences in scale and focus complicates CDK. Agricultural advisors and producers ought to not only use the same language to enhance understanding of effective CSA use. For instance, rather than use numbers and figures without a tangible reference point, advisors ought to frame content in terms of producers' costs (e.g., diesel, tractor use). Changes in communication style can help decrease knowledge gaps and producers' hesitancy to adopt CSA and increase the efficiency of CDK. The strength of CDK is its potential to aid in the research and development of technologies that are more meaningful and useable for end-users (Woodall et al. 2021). Learning about the perceptions of weather, climate, and CSA can help the research-Extension team to adjust events and projects to fit stakeholder needs and interest, which will also increase trust in the science. One such example was the irrigation scenario game (summer 2021), which showed how stakeholders use weather information to make irrigation decisions. This event served as a vital part of CDK. Stakeholders enjoy "serious games" in which they can interact with their neighbors and learn from each other. This game allowed researchers to learn the perceptions of stakeholders about irrigation scheduling and weather. Overall, the irrigation game was one step toward CDK about CSA.

Sydnor and Molnar's (2020) research indicated a long-term gap in technology transfer within the state and that building relationships between stakeholder groups could increase knowledge. As the authors called for in their study, the FOF project has endeavored to help increase knowledge via relationship-building. The FOF drew from Bartel's work (e.g., engagement processes, participatory approaches) to create a learning network as community can serve as a "powerful social tool" for improving decision support capacity and increase CDK. Community can propel adoption by allowing producers to learn from each other (Sydnor and Molnar 2020). Collective learning and community are vital parts of the FOF project that can help to fill the gap in previous studies. Nevertheless, the research-Extension team continues to face challenges in the implementation of participatory practices (Worosz et al. 2024). More work is needed to understand how to build community and conduct CDK projects.

Future Research

Further study is needed to learn how agricultural advisors perceive, understand, and speak about CSA issues. In particular, there was a lack of nutrient management data in agricultural advisors in this thesis. Further study is also needed into how Extension agents and crop consultants advise producers. Studying the exchange of knowledge between advisors and producers can provide researchers with a deeper understanding of perceptions and develop better content and approach to field days. This would improve the CDK process. In addition, future research should illustrate that using CSA can outweigh the perceived disadvantages. Many producers focused on the negative aspects of CSA including increased costs and implementation time. Methods to increase knowledge and aid producers in understanding the long-term benefits of CSA to individual farm operations should be considered.

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